DOCUMENT RESUME

ED 226 281 CG 016 474

AUTHOR Tieger, Todd; Felfoldy, Gary L.
TITLE The Criterion Validity of Work Time Estimation Methods.
PUB DATE 24 Aug 82
NOTE 20p.; Paper presented at the Annual Convention of the American Psychological Association (90th, Washington, DC, August 23-27, 1982).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Evaluation Methods; Job Performance; Occupational Information; Predictive Validity; *Time; *Validity
IDENTIFIERS *Estimation; *Work Measurement

ABSTRACT

An increased need for better information about labor costs associated with many aspects of telephone company operation led to research by the Bell System on work time estimation methods. Several studies were conducted under different field conditions to test the concurrent validity of work time estimation data in comparison with two different methods of work measurement, i.e., work times derived from self-reports and work times derived from productivity measures. The basic approach of the studies involved: (1) analyzing and flowcharting work process; (2) gathering estimates of time for each discrete activity; (3) gathering data to assemble estimated work times for larger work process segments; and (4) gathering data to assess concurrent validity of work time estimates with the traditional methods of work measurement. Results showed that estimated work times predicted alternative measures of work time with varying accuracy; prediction of self-reported work times was very accurate while prediction of production-based work times was tentative. The findings suggest an overall pattern of robust prediction of criterion measures of "true" work time. (JAC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED226281

The Criterion Validity of Work Time Estimation Methods

Todd Tieger
Bell Laboratories
Piscataway, New Jersey

Gary L. Felfoldy
Human Performance Systems
Bernardsville, New Jersey

Paper presented at the annual convention of the American Psychological Association, Washington, D.C., August 24, 1982.

CG 016474

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Todd Tieger

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Abstract

Work time estimation methods have been used in a variety of contexts to measure Bell System work activities for the last nine years. This paper presents the results of two classes of validation studies, comparing estimates of work time to: (1) work times derived from self-reports, and (2) work times derived from productivity measures. Results show that estimated work times, as obtained with the procedures outlined in this paper, predict alternative measures of work time with varying degrees of accuracy. Prediction of self-reported work times is very accurate while the prediction of production-based work times is more tentative. These findings, along with previous reports of the relationship of estimated work times to observed (stopwatch) measures of work time (Butler, 1981) suggest an overall pattern of robust prediction of criterion measures of "true" work time.

1. Introduction

In recent years, the Bell System has increasingly recognized the need for better information about labor costs associated with many aspects of telephone company operations. However, the constraints and costs of traditional means of measuring work times have, until recently, deterred a systematic response. Traditional methods of work measurement such as time-and-motion and work sampling are typically costly and often intrusive. In addition, since these methods require that the work processes under study be clearly observable as well as frequent enough to measure reliably, many Bell System work activities cannot be measured with these methods at all. To meet the need for low cost, non-intrusive, and accurate work time data, the Human Performance Engineering Department at Bell Laboratories began research nine years ago to develop work time estimation methods for general Bell System application.

The basic approach used in the studies we will be discussing entails: (1) carefully analyzing and flowcharting of the work processes of interest; (2) gathering estimates of the range and modal tendencies of work times for each discrete work activity; (3) gathering any additional data required to assemble estimated work times for larger segments of the work process; and (4) gathering data to assess the concurrent validity of work time estimates with the use of traditional methods of work measurement for a subset of work activities. Work time estimates are gathered in group estimation sessions on carefully written activity description forms, called "case problems." Although each individual

provides an independent set of estimates, group sessions are administered to gather a large amount of work time data quickly. Thus, estimation methods clearly represent a low-cost alternative to traditional work measurement methods. Furthermore, since individual estimators are actively encouraged to draw on their own work experiences in making their work time estimates, these methods can also be applied to work activities that are not easily observed and that do not occur frequently.

The need for empirical research on the reliability and validity of work time estimation data was recognized several years ago and incorporated in the design of early studies. These studies showed that estimation methods generated work time data with high test-retest reliability. Furthermore, when estimates of work time were compared with traditional stopwatch measures of observed work times, the results of the two measurement approaches were highly correlated[1]. In these studies, the work activities that were measured were discrete and easily observable. Furthermore, the work activities timed in this fashion were identical to the estimation case problem descriptions independently presented to estimators. The high predictive validity of estimated work times compared to work times gathered by traditional observational method was partially a function of the care taken to assure this direct

---

1. Butler, T.W. Reliability and Validity of Work Time Estimates. Paper presented at the American Psychological Association Convention, Los Angeles, August 24, 1981.

observability and comparability of the work activities involved in the study.

This paper presents the results of several studies on the concurrent validity of work time estimation data in comparison with two different methods of work measurement under difficult field conditions. An additional difference between the studies reported here and the previously cited comparisons of estimated and observed work times arises from the need to compare aggregates of estimated work times with alternative measures of work time for larger "chunks" of the work process. This was dictated by constraints of cost reduction, logistics, and coordination in the gathering of validation data in the jurisdictions studied. As we shall see, the overall pattern of results suggests continued confidence in the validity of work time estimation methods.

2. Methods

Since previous reports presented at last year's APA convention[2] have detailed the procedures for work analysis and estimation of work times, we will not spend much time on these two study components. Suffice it to say that a set of flowcharts similar to that shown in Figure 1 were developed and field tested extensively. Workers and first-level supervisors with a minimum of one year's recent experience on the jobs

---

2. Butler, Op. Cit.

involved in the study participated in carefully administered group estimation sessions. Estimation case problems asked workers to recall their experiences on carefully defined work activities and then estimate the minimum, maximum, and most likely work times for each (Figure 2). This format was derived from the PERT method of program evaluation.[3] The PERT scheme for weighting the three work time estimates was also used to derive a single average PERT score for each estimator on each case problem, and then these were averaged across all estimators to produce a mean estimated work time for each case problem.

2.1 Gathering Data to Aggregate Work Times

The third component of an estimation study entails gathering additional data as required to assemble estimated work times for any desired larger ensemble of work activities. In practice, this means designing studies to gather data on the probability of occurrence of each work function in the sequence of typical work activities. This translates into information on probabilities for the flow of work down each branch of a decision tree on the flowcharts derived in the work analysis phase (see Figure 1). Similarly, information must be gathered about the average configuration of work activities for activities whose work times are sensitive to the number or complexity of work units involved (e.g., installation times depend on the number of units of electrical

---

3. Program Evaluation Research Task (PERT) Summary Report: Phase 1. Department of the Navy, Washington D.C.: National Technical Information Service, July 1958.

transmission equipment installed on a circuit). Thus, probability of occurrence and average configuration data are the "glue" of a work time estimation study, insofar as they allow the aggregation of the separately estimated work times identified in the work analysis phase.

Aggregation of estimated work times is accomplished by assembling estimated mean times in a linear equation, with each estimate weighted by its objectively determined probability of occurrence. The explicit definition of items to be included in the linear equation constitutes what we call an "estimation model." The parameters of the estimation model are typically defined by the user's intended application. Thus, an estimation model for determining the reduction in work times (and, hence, labor costs) associated with the introduction of an automated support system would specify the exact inclusion and exclusion criteria for work functions involved in the new versus the old work process. Alternatively, an estimation model for determining the total labor cost associated with provisioning a type of telephone company service would typically specify inclusion of all work functions in a complete model. The estimation model is therefore a mathematical expression of a user-defined application of estimation data.

2.2 Gathering Validation Data

The fourth component of an estimation study entails gathering a sample of independently measured work times for a representative subset of work activities involved in the project, and comparing these with estimation data for equivalent units of work activity. This paper describes the

methods and findings of the validation studies conducted within the framework we have been describing. To date, we have used two types of validation studies. These have compared estimated work times to: (1) self-reported work times and (2) work times derived from productive output. We now introduce each of these approaches and the resultant findings in turn.

3. Self-Report Validation Studies

3.1 Self-Report Methods

Figure 3 shows the format of a typical timing sheet used in gathering self-reports of work times for the first type of validation study. This basic format was used in three states to measure a diverse range of work activities for which estimates of work time had already been collected. A start/stop method of reporting work times was used in preference to recording elapsed times, since work activities are typically interrupted. Work times were recorded to the nearest minute with the use of a wall clock or wristwatch. Work activities listed on the timing sheet were carefully defined to correspond both with "natural" units of work activity and with estimation case problem definitions. The timing sheets were filled out by all personnel who fit the same qualifications imposed on the selection of estimators. Finally, the typical sample of the study included several geographic locations and a one month census of work activity in an effort to control for differences in work activities associated with organizational, geographic, and temporal variations in work activity. However, since local Operating Company

personnel determined the priorities and level of support for each study, characteristics of the self-report sample varied considerably from study to study.

3.2 Results: Relationship of Estimated and Self-Reported Work Times

The relationship between self-reported and estimated work times from all the study data we have compiled to date across locations is plotted in Figure 4, and described numerically in the least-squares regression equation shown. The high mutual predictability between self-report and estimation measures of work time is shown in the correlation coefficient, $r = 0.962$ ($p < 10^{-5}$, with 8 df). Estimated work time accounts for 92.5% of the variance in self-reported work times ($r^2 = 0.925$).

4. Production Data Validation Studies

4.1 Production Data Methods

The second type of validation study we have used involves the comparison of estimated work times to work times derived from production data. The productive output of a group of working individuals can often be directly monitored in terms of the number of work units completed in a given base time period. If this productive output can be associated with a clear measure of the total productive labor time spent processing that output, then an average measure of work time for completion of one work unit can be computed. To achieve this goal, it is essential that all non-productive employee time be systematically excluded from

association with the productive activities of interest. Then, if the total work activity profile encompassed by the production data can be shown to correspond exactly to a discrete set of work activities already described to estimators, it is possible to compare estimated work times with the unit work time computed from the production data. This approach was applied successfully in two separate validation studies conducted within the framework we have been discussing.

Comparison of estimated work times with production data for an entire work process is an inherently complex matter. Production records are typically full of unusual instances that reflect the true reality of on-going work activity in the larger sense of the term. Estimated work times may encompass some of the variation in the work process within the three-point estimation format. However, the case problem descriptions of each activity read by estimators were necessarily written as if the world were more standardized.

4.2 Results: Relationship of Production Data to Estimated Work Times

A comparison of estimated work times with production-based unit work times is plotted in Figure 5 for the available data from two validation studies. Again, the overall relationship of the two work time measures is orderly. This is expressed mathematically by the least-squares regression equation also shown in Figure 5. The correlation of estimated work time to production-based unit work time in these studies was r = 0.894 ($p < .01$ with 4 df). The percentage of variance in production-based unit work times accounted for by estimated work times was 80% (r^2

= 0.800).

The accuracy of the prediction between these measures of work time is lower than that reported above for self-reported and estimated work times. This is probably because production data typically need to be compared to an aggregate or composite of estimated work times via an estimation model. The larger the segment of work activity covered by production data, the greater the likelihood of errors in prediction from component estimation times. In any case, it is evident that more data are needed before the result shown in Figure 5 can be viewed as a definitive statement of the relationship between these two measures of work time.

5. Discussion

It is clear from this analysis that estimated work time, as obtained with the methods we have been discussing, allows robust prediction of alternative measures of work time. The implication of these findings is that the four work time measurement methods studied to date (estimation, direct observation, self-report, and production records) are interrelated. Each method, in turn, can be taken as a predictor of an assumed underlying construct of "true" work time.

It is the user's responsibility to select a criterion measure of work time for each measurement application. If the chosen criterion is other than estimation, estimation methods can still be used to achieve a substantial cost reduction compared to traditional work measurement

methods. This is accomplished by using a validation study in conjunction with estimation of the full set of work activities.[4] That is, the validation study can be designed to measure a subset of work activities using the selected criterion work measurement method. Then, the regression equation expressing the relationship of estimated to criterion measures for this subset of work activities can be used to adjust estimates of work time for the entire set of work activities.

The studies reported in this paper suggest continued confidence in the validity of work time estimation as a work measurement method. The inclusion of a validation component in on-going estimation studies within the Bell System will assure that each application of the methods provides additional data on this point.

---

4. Domangue, J.C. Unpublished manuscript. February 2, 1982.

Figure 1

Format of Estimation Study Flowchart

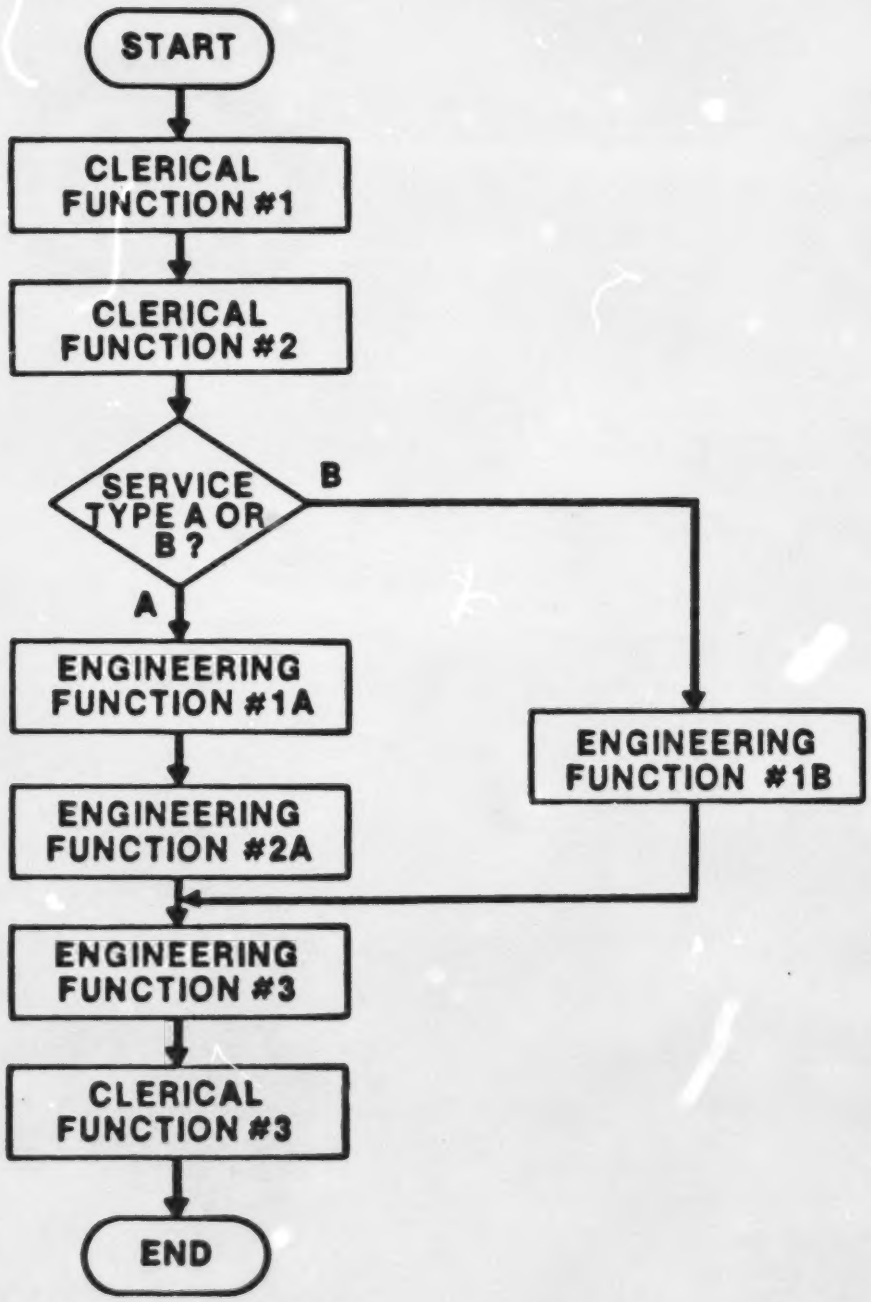

Figure 2

Estimation Case Problem Format

Case Problem Number _____

Activity Title

_____

_____

Activity Description

Begins	May Include	Ends
• _____	• _____	• _____
• _____	• _____	
	• _____	
	• _____	

Does Not Include

- _____
- _____
- _____

Estimated Work Time:

Minimum	Maximum	Most Likely
_____	_____	_____

Figure 3

Format of Timing Sheet
for Self-Report Studies

Activity Timing Sheet

- **Instructions**

  Please fill out all requested information for each work order. Provide start and stop times to the nearest minute only using a wristwatch or wall clock. Please do not place your name on this Timing Sheet.

- **Order Information**

  Work Order Number _____

  Date Worked _____

  Service Type _____

  Order Status (circle one):

  1. Active 2. Pending 3. Pre-survey

- **Work Time Information**

Activity Description	Start	Stop
1. Design equipment, including: • _____ • _____ • _____		
2. Test circuit, including: • _____ • _____		
3. Administrative paperwork		

When you have completed this form, return to _____.

FIGURE 4

Least-Squares Regression Equation and Plot of Estimated vs. Self-Reported Work Times

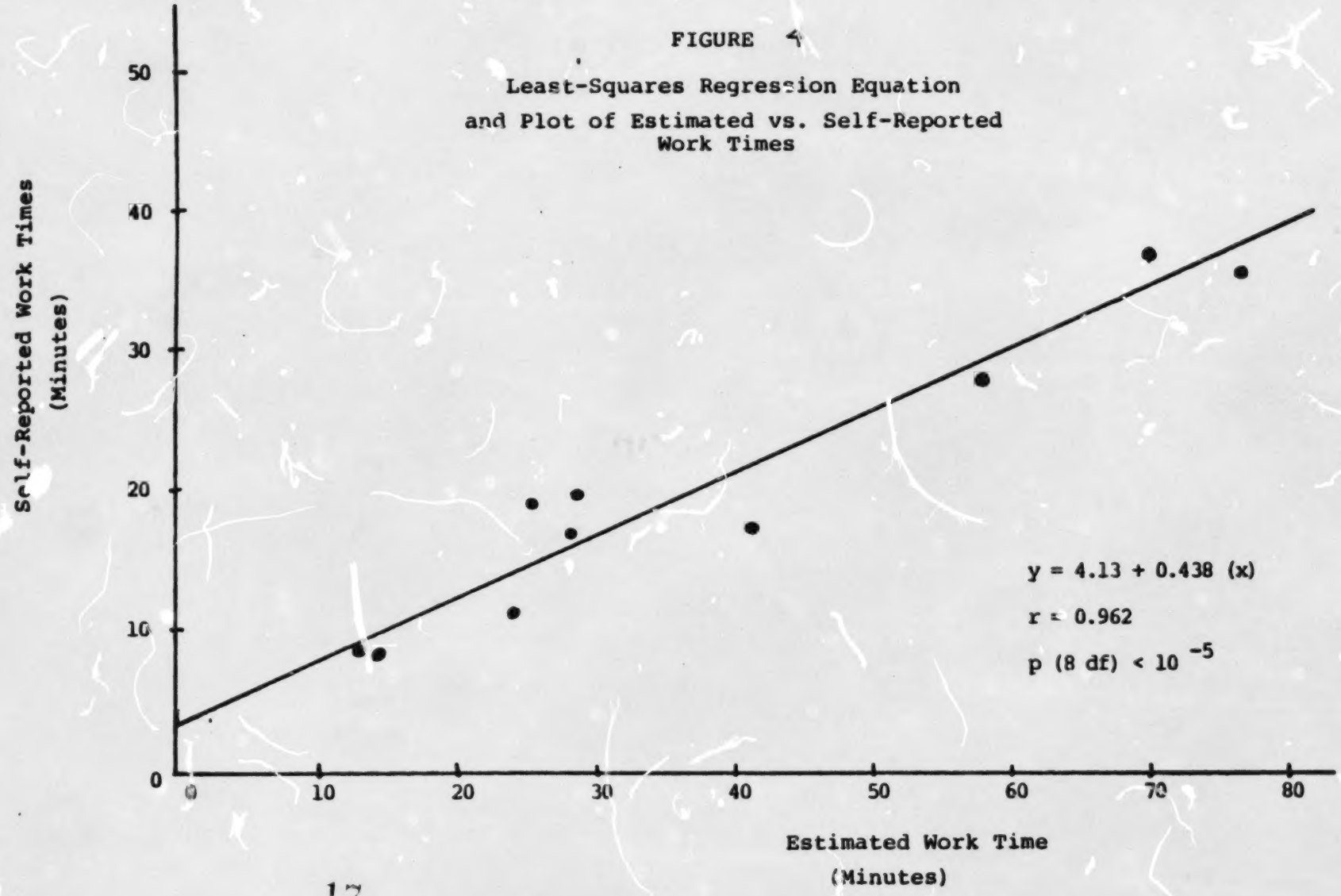

Figure 5

Least-Squares Regression Equation and Plot of Estimated vs. Production-Based Work Times